EFFICIENCY AND STEAM CONSUMPTION TESTS ON THE ALCO VAPOR ENGINE

J. W. WRIGHT
G. W. WILLIAMSON, III

1899

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Alco Vapor Engine.
A
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Efficiency and Steam Consumption Tests on the Alco Vapor Engine.

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As the name of the engine implies, vapor of alcohol is used expansively in the cylinders although in testing the engines at the factory or shop steam is ordinarily used. In these tests it was intended to use both but owing to the limited time at our command this course was prevented and all the tests made were on the engine when using steam.

The particular engine used was one supposed to be three horse-power and the general type is a three cylinder single acting and single crank engine.

The cylinders are set at 120° apart, the head of the lower one forming the bed plate of the engine which was narrow and

sloped in the direction of the shaft. This slope is to give the engine the necessary rake when used for a marine engine.

The indicator rig was driven from a pin screwed into a hole in the fly wheel, the eccentricity of the pin being equal to the length of the crank. Motion was transmitted from the pin to a slide-bar by means of a connecting rod equal in length to the connecting rod of the engine. Two holes were made in the fly wheel and were placed 120° apart so that by changing the pin from one hole to the other either of the upper cylinders could be indicated. This arrangement of the rig reproduced the stroke of the engine correctly and of full length, i. e. 3".

The lower cylinders were not included at all since the piping necessary to connect up the indicator would have increased the clearance volume several times. Tests were run on both of the upper cylinders and the cards show that the cut off on each is practically the same at the same notch. (See prints of cards).

Conditions were getting to allowing a steam to the first which drove the indicator rig and thus working a reciprocating counter.

In these tests the cylinder designated "right" was the one on the right hand side of the engine looking from the coupling end.

Cards were taken from right and left hand cylinders at varying points of cut off, separate tests being run

for each of the selected points, up to the twelfth notch. At this point the engine carried steam for ⅔ of the stroke and over 50% more of the rated I.H.P. was developed.

The principal difficulty met with in running the tests was that of keeping the brake load sufficiently constant for since the engine had no governor the speed had to be regulated entirely by the brake. This regulation was made more difficult from the fact that no provision was made for dissipating the heat developed and as this had already become excessive at the 12th notch it was thought best carry the tests no further.

In the tests while the steam was reversed, it was found

that the friction load could be kept more nearly constant by a judicious application of soap, to the rim of the flywheel.

Cards were taken every five minutes during the test and readings of the brake load were taken at the same times on the cards.

The water was read every five minutes during the shorter tests and every ten minutes during the longer ones.

Steam was condensed in a surface condenser and collected in buckets and weighed on a spring balance. (See calibration pa. 38)

Steam gauge was used on the steam pipe at the engine throttle valve and the pressure was noted every five minutes.

This gauge merely served as a check. The usual gauges were used in the calibration of the indicator, thus necessitating a calibration of the gauge itself, which is given below:

Calibration of Gauge 260627.

Tester	Gauge up	Gauge Down
5	6.0	6.6
10	11.4	11.9
15	15.9	16.4
20	20.8	21.4
25	25.6	26.3
30	31.2	31.6
35	36.0	36.4
40	40.5	41.5
45	45.6	46.4
50	50.5	51.3
55	55.1	55.9
60	60.4	61.2
65	65.0	66.0
70	69.7	70.6
75	74.7	75.5
80	79.8	80.6
85	84.6	85.4

The method of calibrating indicator springs as carried out at Lehigh College, is given in Trans. A.S.M.E., Vol 15, page 459, and the investigators there found that the present practice as regards original calibrations varies and that consequently some springs are more nearly right when calibrated hot and vice versa.

The results showed that the practical method now to calibrate indicator springs hot when they were to be used hot, since if the constants got by them from the cold calibration were used they would lead to an average error of over 2%.

The spring used in all these tests was accordingly calibrated hot and this was done by connecting up the indicator to the steam line and reading the pressures from the fre-

viously calibrated gauge. By throttling the steam the pressure could be adjusted and marks were made for both ascending and descending pressures at every 10 lbs. by gauge.

The corrected gauge readings were then marked on the cards for the points read, for both up and down readings. Then the vertical distances between any two consecutive lines was measured to .01" and this distance (difference between) into the corrected pressures at the points gave the scale of the spring. This method gives varying scales for each card, the mean of which is taken. Then the mean of both up and down reading taken the final spring scale which is used in the working up of results is obtained.

Results of Indicator Spring Calibration

Up.

Press.	Cor. Gauge	Gauge Diff.	Distance	Scale
0	0			
		9.4	.21"	44.8
10	11.4			
		10.4	.19"	54.7
20	20.8			
		9.3	.22"	42.3
30	31.2			
		10.0	.20"	50.0
40	40.5			
		9.9	.19"	52.1
50	50.5			
		9.3	.19"	48.9
60	60.4			
		10.1	.19"	53.1
70	69.7			
80	79.8			
			Sum	345.9
			Mean	49.41*

Results of Indicator-Calibration

Drum.

Press.	Cor. Gauge	Gauge Diff.	Distance	Scale
0	0			
		———	———	
10	11.9	9.5	.22"	43.3
20	21.4	10.2	.19"	53.7
30	31.6	9.9	.21"	47.2
40	41.5	9.8	.19"	51.5
50	51.3	9.9	.21"	47.2
60	61.2	9.4	.19"	49.4
70	70.6	10.0	.21"	47.6
80	80.6			

Sum	339.9
Mean	48.56

It will be noticed that the scale was not calculated between the 0 and 10 lbs. marks since between these two points the results are affected too greatly by friction.

Mean up scale +1.71

" down " +3.07

Sum 7.97 Mean = 48.985 lbs.

Mean Spring Scale = 49.00 lbs.

This resulting scale was used in calculating the horse-powers which without this calibration would have been two per-cent in error from this cause alone.

Following are given the results of the several tests. It will be noticed they are marked by "notches". This will be understood from the sketch on page 25, of the controlling lever by which cut off is adjusted.

Notch 6.

Efficiency and Water.

M.E.P. card 1 $\frac{49 \times 2.17}{2.93} = 36.05$ IHP $= 1.606$

M.E.P. card 2 $\frac{49 \times 2.16}{2.97} = 36.05$ I.H.P. $= 1.606$

M.E.P. card 3 $\frac{49 \times 2.166}{3.0} = 35.2$ I.H.P. $= 1.57$

M.E.P. card 4 $\frac{49 \times 2.20}{2.98} = 36.05$ I.H.P. $= 1.606$

$4 \overline{)6.388}$

Water Total $62\frac{1}{4}$ lbs
Tare $15\frac{1}{2}$ ..
net $46\frac{3}{4}$ ..

Mean I.H.P 1.597

Brake 20 lbs. Total
.453 Tare
19.547 lbs. Net.

Counter 68987
64819
4168

B.H.P. $= 1.443$

Time 15 minutes.
$\frac{4168}{15} = 278$ Rev. p.m.

Efficiency $\frac{1.443}{1.597} = 90.3\%$

Water per I.H.P. per hour $= \frac{4 \times 46.75}{1.597} = 117$ lbs.

Test no. 1. R. Cyl.

Notch 6.

Efficiency and Water.

M.E.P. card 1 $\frac{49 \times 1.896}{2.95} = 31.5$ I.H.P = 1.893

M.E.P. card 2 $\frac{49 \times 1.97}{3.04} = 31.7$ I.H.P. = 1.905

M.E.P. card 3 $\frac{49 \times 1.98}{2.97} = 32.9$ I.H.P. = 1.96

3 | 5.758

mean I.H.P. 1.919

Water Total 47.25 lbs.
Tare 12.00 ..
Net 35.25 ..

Brake 19.81 lbs
Tare .453 ..
19.357 ..

Counter 61627
57880
3747

B.H.P. 1.83.

Time 10 min.
$\frac{3747}{10} = 375$ Rev. p.m.

Efficiency $\frac{1.83}{1.92} = 95.2\%$

Water per I.H.P. per hour = $\frac{6 \times 35.25}{1.919} = 110.5$ lbs.

Test no. 2 L. Cyl.

Notch 8.

Efficiency and Water.

M.E.P. card 1 $\frac{49 \times 2.50}{3.06} = 40.$ I.H.P. $= 2.775$

M.E.P. card 2 $\frac{49 \times 2.50}{3.11} = 39.45$ I.H.P $= 2.735$

M.E.P. card 3 $\frac{49 \times 2.656}{3.15} = 41.3$ I.H.P $= 2.88$

M.E.P. card 4 $\frac{49 \times 2.81}{3.17} = 38.55$ I.H.P $= 3.01$

$4)11.1$

mean I.H.P. 2.85

Water Total $77\frac{7}{8}$ lbs.

Tare 18 "

net $59\frac{7}{8}$ "

B.H.P. 2.65

Brake 23.5 lbs.

Tare $.453$ "

23.047 "

Counter 76195

69702

6493

Time 15 min.

$\frac{6493}{15} = 433$ rev. p.m.

Efficiency $= \frac{2.65}{2.85} = 93\%$.

Water per I.H.P. per hour $= \frac{4 \times 59.875}{2.85} = 84$ lbs.

Test no. 3 R. Cyl.

Notch 12.

Efficiency and Water.

M.E.P. card 1 $\frac{49 \times 3.99}{3.1} = 63.1$ I.H.P = 4.55

M.E.P. card 2 $\frac{49 \times 4.02}{3.17} = 62.1$ I.H.P = 4.48

2 | 9.03

mean I.H.P. 4.515

Water Total 34 11/16 lbs.
Tare 6 "
net 28 11/16 "

Brake 35.5 lbs.
Tare .453 "
net 35.047 "

Counter 77907
75657
2250

B.H.P = 4.18

Time 5 min.
$\frac{2250}{5} = 450$ Rev. p min.

Efficiency = $\frac{4.18}{4.515} = 92.4\%$.

Water per I.H.P. per hr. = $\frac{28.687 \times 12}{4.515} = 83.7$ lbs.

Test no. 4 R. Cyl.

Notch 2.

Water Consumption.

M.E.P. card 1 $\frac{49 \times .19}{3.07} = 30.35$ I.H.P. = .201

M.E.P. card 2 $\frac{49 \times .195}{3.07} = 30.8$ I.H.P. = .205

M.E.P. card 3 $\frac{49 \times .185}{3.08} = 27.7$ I.H.P. = .1755

3 | .6015

mean I.H.P. .2005

Water Total 25.25 lbs.
Tare 6 "
19.25 "

Time 10 min.

Water per I.H.P. per hr. = $\frac{19.25 \times 6}{.2005} = 577$ lbs.

Test no. 5 R. Cyl.

Notch 2.

Water Consumption.

M.E.P. card 1 $\frac{19 \times .11}{2.97} = 34.6$ I.H.P = .1834

M.E.P. card 2. $\frac{49 \times .183}{2.93} = 30.55$ I.H.P = .162

M.L.P. card 3 $\frac{49 \times .246}{2.94} = 32.6$ I.H.P .173

3)·5184

mean I.H.P .1728

Water Total $25\frac{5}{8}$ lbs.

Tare $\frac{6}{19\frac{5}{8}}$ "

Time 10 min.

Water per I.H.P. per hr = $\frac{19.625 \times 6}{.1728} = 679$ lbs.

Test no. 6 L. Cyl.

Notch 4.

Water Consumption.

M. E. P card 1 $\frac{49 \times 1.016}{3.07} = 16.25$ I. H. P = .981

M. E. P card 2 $\frac{49 \times 1.013}{3.1} = 16.0$ I. H. P = .989

M. E. P card 3 $\frac{49 \times 1.11}{3.07} = 17.7$ I. H. P = 1.065

M. E. P card 4 $\frac{49 \times 1.163}{3.13} = 19.0$ I. H. P 1.147

M. E. P card 5 $\frac{49 \times 1.203}{3.25} = 18.1$ I. H. P = 1.092

M. E. P card 6 $\frac{49 \times 1.146}{3.10} = 18.1$ I. H. P = 1.092

M. E. P card 7 $\frac{49 \times 1.102}{3.1} = 17.4$ I. H. P = 1.055

$\frac{7)7.421}{1.060}$

mean I. H. P

Water Total 105 7/8 lbs.

Tare $\frac{24}{81.875}$ "

Time 30 min.

Water per I. H. P hour $\frac{2 \times 81.875}{1.060} = 154.5$ lbs.

Test no. 7 R. Cyl.

Notch 4.

Water Consumption.

M.E.P. card 1 $\frac{49 \times .926}{2.81} = 16.13$ I.H.P = .705

M.E.P. card 2 $\frac{49 \times 1.03}{2.9} = 17.4$ I.H.P = .761

2)1.466

mean I.H.P .733

Time 7¼ min.

Water Total 25.3 lbs.

6

19.3 "

Water per I.H.P per hr. $\frac{19.3 \times 60}{7.25 \times .733} = 218.5$ lbs.

Test no 8 L. Cyl.

Notch 6.

Water Consumption.

M.L.P card 1 $\frac{49 \times 1.91}{3.07} = 30.5$ I.H.P = 2.225

M.E.P card 2 $\frac{49 \times 1.88}{3.05} = 30.2$ I.H.P = 2.205

M.E.P card 3 $\frac{49 \times 2.02}{3.20} = 31.0$ I.H.P = 2.255

3)6.685

mean I.H.P 2.228

Time 10 min.

Water per I.H.P per hr = $\frac{6 \times 59.81}{2.228} = 107.25$ lbs.

Test no. 9 R. Cyl.

Notch 6.

Water Consumption.

M.E.P. card 1 $\frac{49 \times 1.73}{3.07} = 27.6$ I.H.P. = 2.015

M.E.P card 2 $\frac{49 \times 1.73}{3.5} = 24.2$ I.H.P = 1.795

M.E.P. card 3 $\frac{49 \times 1.7}{3.18}$ 26.2 I.H.P = 1.91

3 | 5.720

mean I.H.P 1.906

Water Total 56 $\frac{7}{16}$ lbs.

Tare $\frac{12}{44\ \frac{7}{16}}$

Time 10 min.

Water per I.H.P. per hr. = $\frac{44.473 \times 6}{1.906} = 140$ lbs.

Test no. 10. L. Cyl.

Notch 8.

Water Consumption.

M.E.P. card 1 $\frac{4.9 \times 2.51}{3.22} = 39.1$ I.H.P. = 2.165

M.E.P. card 2 $\frac{49 \times 2.49}{3.12} = 39.1$ I.H.P. = 2.165

M.E.P. card 3 $\frac{49 \times 2.53}{3.10} = 40.0$ I.H.P. = 2.215

M.E.P. card 4 $\frac{49 \times 2.50}{3.05} = 40.2$ I.H.P. = 2.225

M.E.P. card 5 $\frac{49 \times 2.47}{3.05} = 39.5$ I.H.P. = 2.205

M.E.P. card 6 $\frac{49 \times 2.463}{3.02} = 40.0$ I.H.P. = 2.215

13.190

mean I.H.P. 2.198

Time 26.3 min.

Water Total 118 1/8 lbs.
Tare 26 "
92 1/8 "

Water per I.H.P. per hr. $= \frac{92.125 \times 60}{26.3 \times 2.198} = 95.7$ lbs.

Test no. 11 R. Cyl.

Notch 12.

Water Consumption.

M.E.P. card 1 $\frac{49 \times 3.938}{3.15} = 61.5$ I.H.P = 4.05

M.E.P. card 2 $\frac{49 \times 3.416}{3.20} = 52.4$ I.H.P 3.32

M.E.P card 3 $\frac{49 \times 3.213}{3.1} = 50.8$ I.H.P = 3.36

M.E.P card 4 $\frac{49 \times 2.833}{3.45} = 40.2$ I.H.P = 2.66

mean I.H.P $4 \overline{)13.38}$ 3.345

Time 15 min.

Total Water 8 pd $\frac{7}{8}$ lbs.
Tare 1 pd 4 "
Net 6 pd 7/8 "

Water per I.H.P per hr $= \frac{6.875 \times 4}{3.35} = 80.1$ lbs.

Test no. 12 R. Cyl.

Engine Constant.

Length stroke — 3" = .25'

Diam. Cylinders - 3" = 7.07"

No. Cylinders — 3

Constant for 1 lb. M.E.P. and 1 revolution per minute:

$$\frac{7.07 \times .25}{33000} = .0001606$$

Brake Constant.

Length of Arm — 16.75" = 1.396'

Constant for 1 lb. net brake load and 1 revolution per minute:

$$\frac{2\pi \times 1.396}{33000} = .000266$$

Mean weight of brake arm which had to be deducted from the total brake in each case was 7½ lbs. = 4.53 lb.

FRONT VIEW

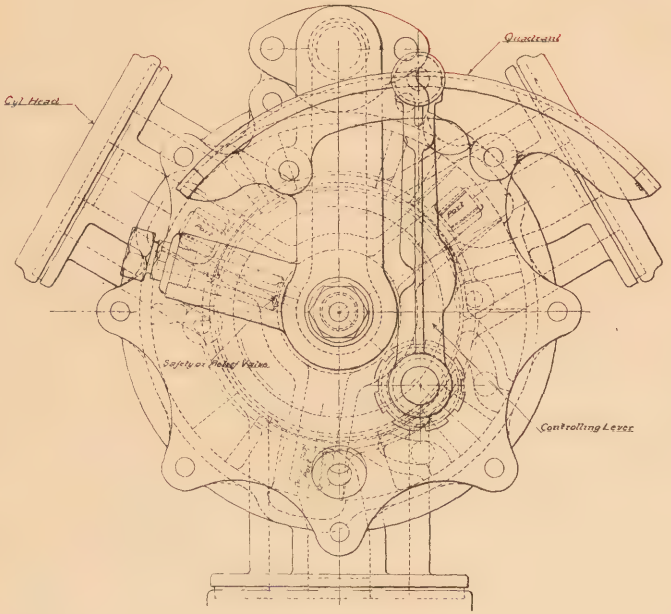


FIG. 1.

FRONT VIEW SHOWING VALVE GEAR

Stationary Rack & Cut-off Valve broken away

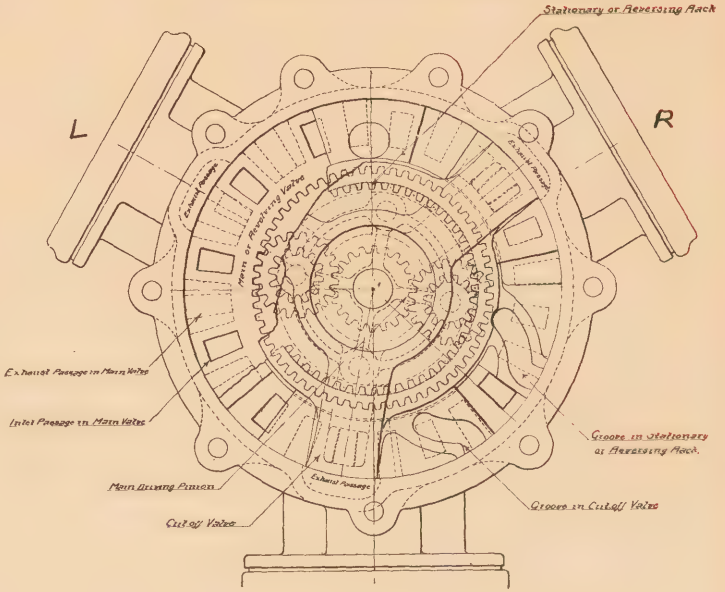
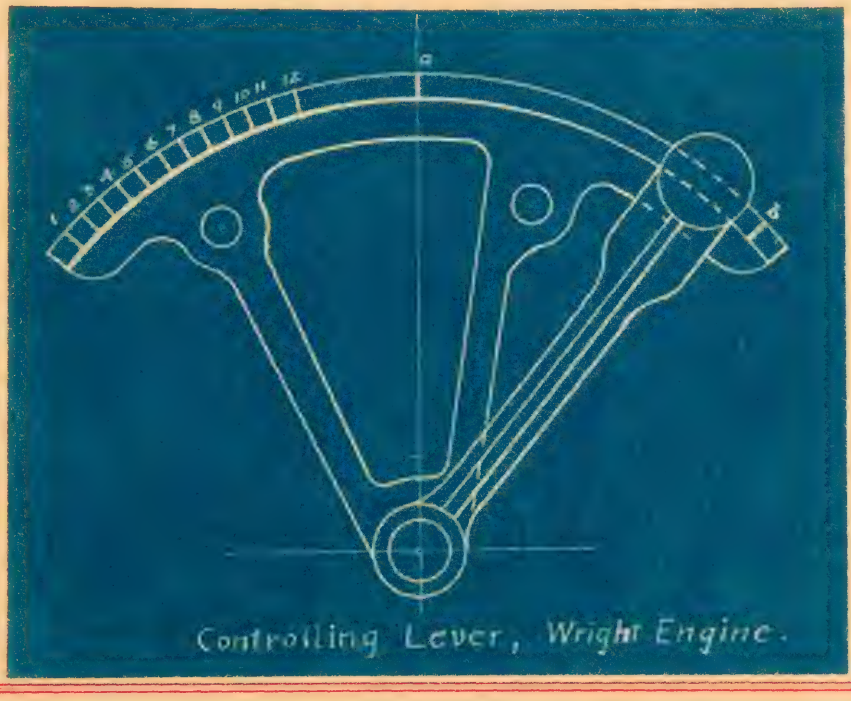


FIG. 2.

Figures 1 and 2 give front views of the engine and in figure 2 the cylinders will be seen marked R and L corresponding to the cylinders indicated which were so designated.

In figs. 1 and 3 will be seen views of the quadrant over which the controlling lever is moved and at any point of which it can be held stationary by allowing the spring pin to fall in one of the notches.



Controlling Lever, Wright Engine.

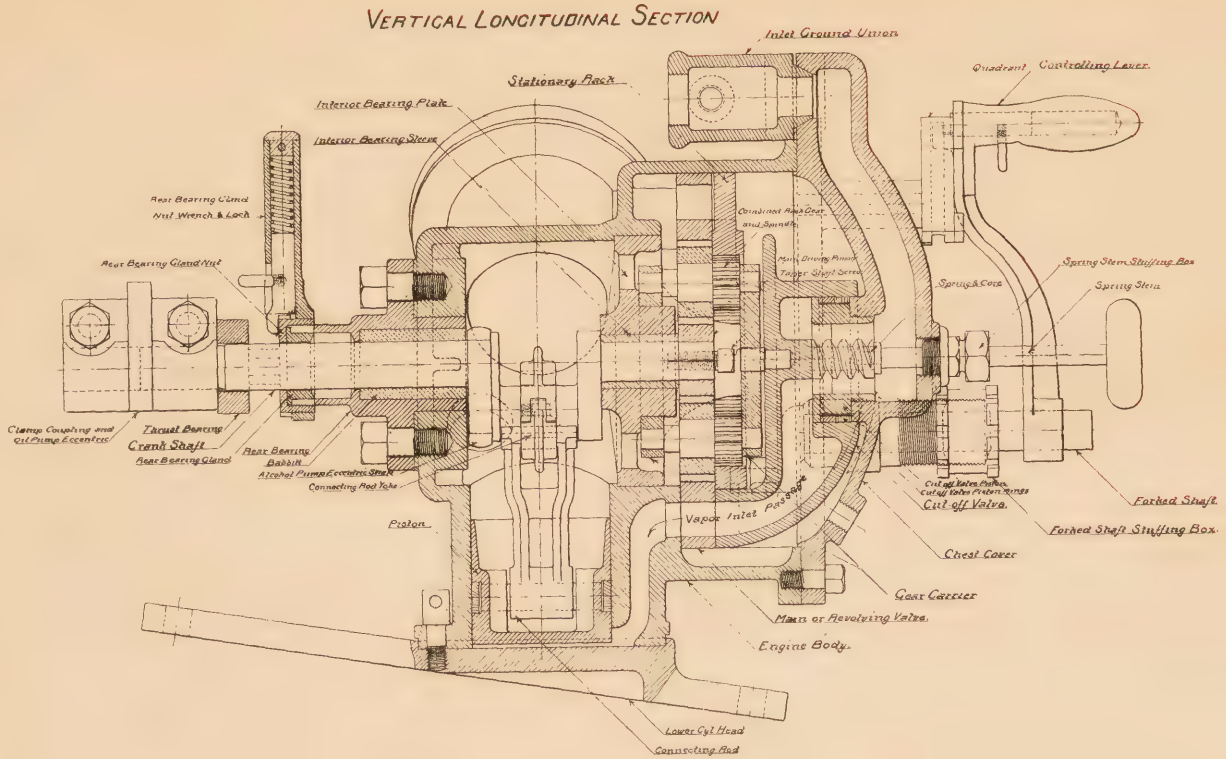

VERTICAL LONGITUDINAL SECTION
Inlet Ground Union
Quadrant
Controlling Lever
Stationary Rock
Interior Bearing Plate
Interior Bearing Sleeve
Rear Bearing Gland Nut Wrench & Lock
Rear Bearing Gland Nut
Spring Stem Stuffing Box
Spring Stem
Spring & Cock
Clamp Coupling and Oil Pump Eccentric
Thrust Bearing
Crank Shaft
Rear Bearing Gland
Rear Bearing Babbit
Alcohol Pump Eccentric Strap
Connecting Rod Yoke
Piston
Vapor Inlet Passage
Cut off Valve Piston Rings
Cut off Valve
Forhead Shaft
Forhead Shaft Stuffing Box
Chest Cover
Gear Carrier
Main or Revolving Valve
Engine Body
Lower Cyl Head
Connecting Rod

FIG. 3.

Figure 4 shows the main valve of the Alco Vapor Engine. It will be seen that it has 12 admission and 12 exhaust

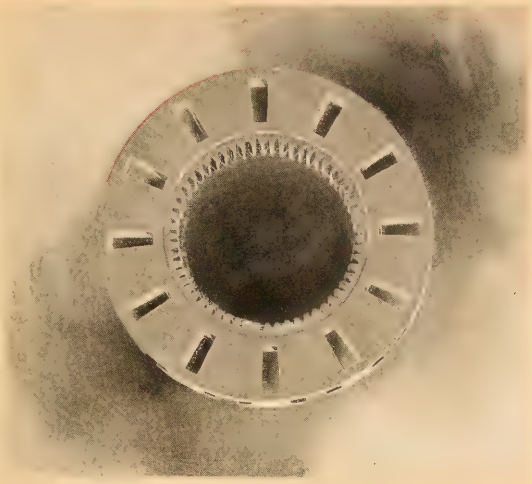
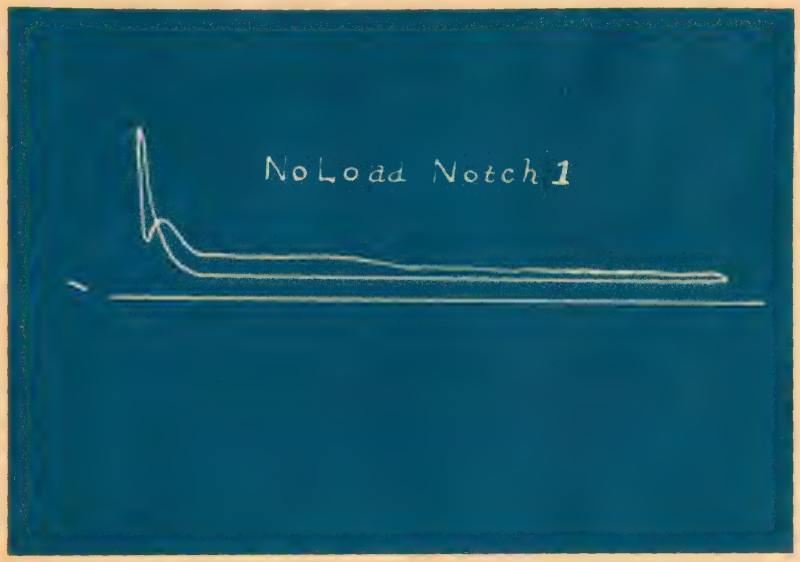


Fig. 4.

ports and it is driven by a small pinion from the main shaft by means of two intermediate wheels. These are so arranged that the valve moves around once to twelve revolutions of the shaft. This small movement of the valve per revolution may in part account for the very high mechanical efficiency obtained.

Following is a card taken with the friction load only, the engine running very nearly up to the speed in the final card shown which was at the

maximum load obtained.

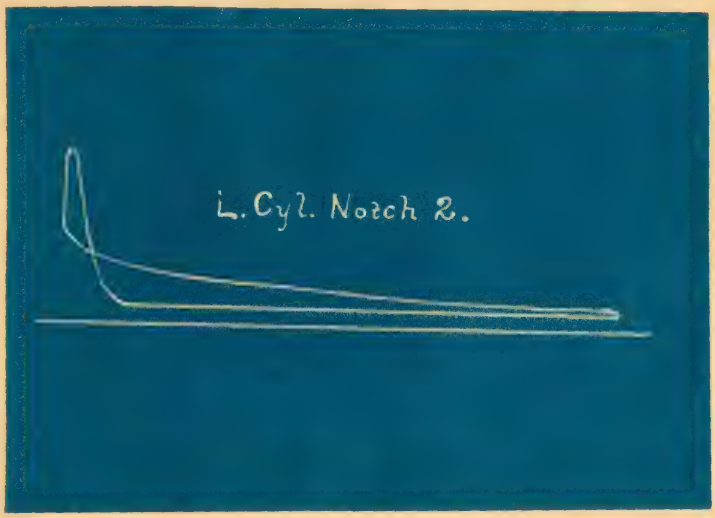


The horse-power of this card is .2 and that of the card obtained on [illegible] is 4.5 H.P.

$\frac{100 \times .2}{4.5} = 4\%+$ or the difference in the areas of the cards shows in this case a loss of over 4% from friction so that the mechanical efficiency of the engine appears to be rather high.

The next card was taken from the cylinder on the opposite side from the

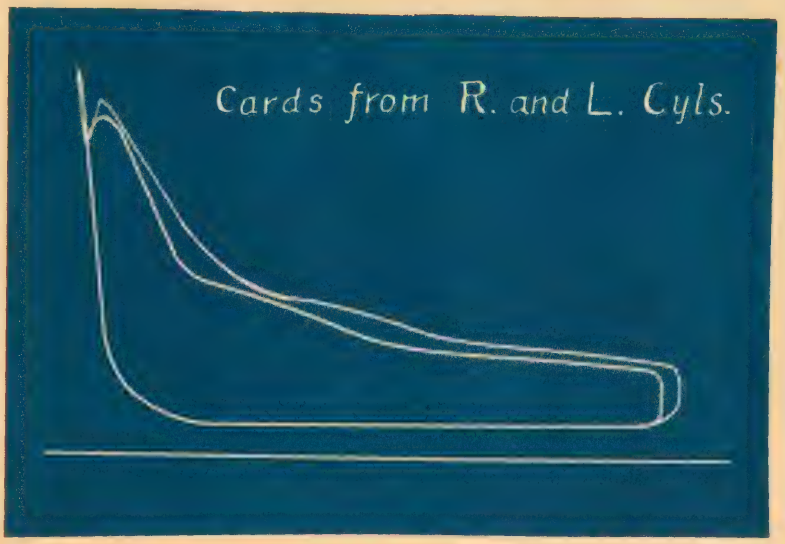
preceding and the engine carried a small load and cut off later.



It will be seen from the next print that it made practically no difference if one cylinder was indicated and the power developed then multiplied by 3 in order to get the total power instead of indicating all three cylinders at once.

The card with the high expansion line was taken from the right hand cylinder and the other

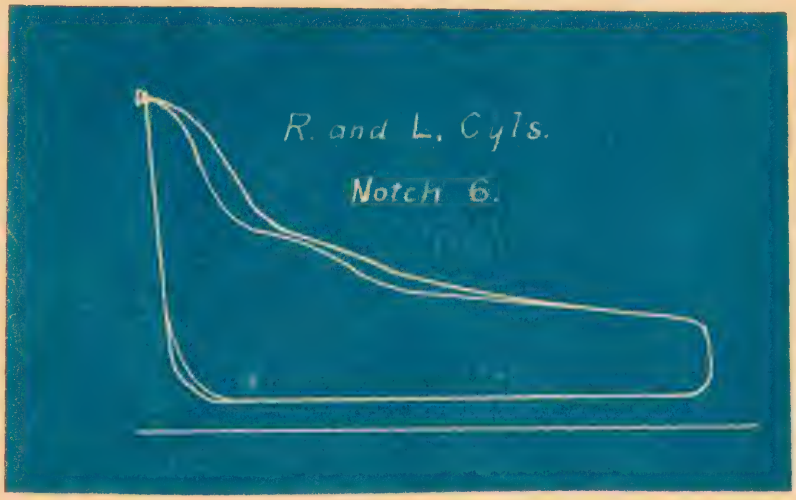
from the left-hand card as to the notch.



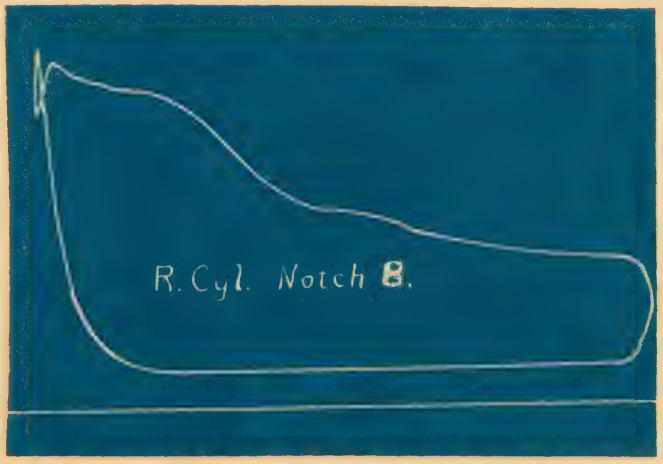
The number of revolutions per minute was identical in each case. The higher expansion line in the card from the right-hand side is accounted for by 10 lbs. difference in the gauge pressures in the two cases. There also seems to have been more strain to the indicator string in case of the card from R.H. end.

In the next set of cards from right and left-hand cylinders the

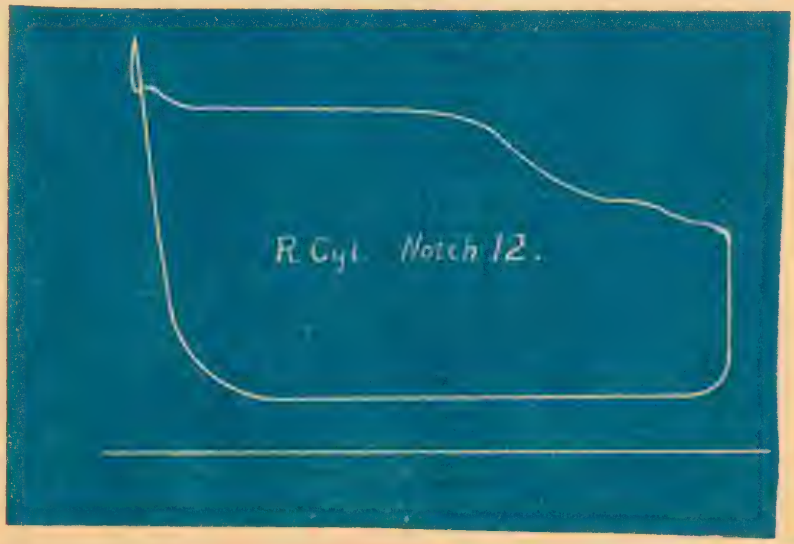
agreement is even more apparent.



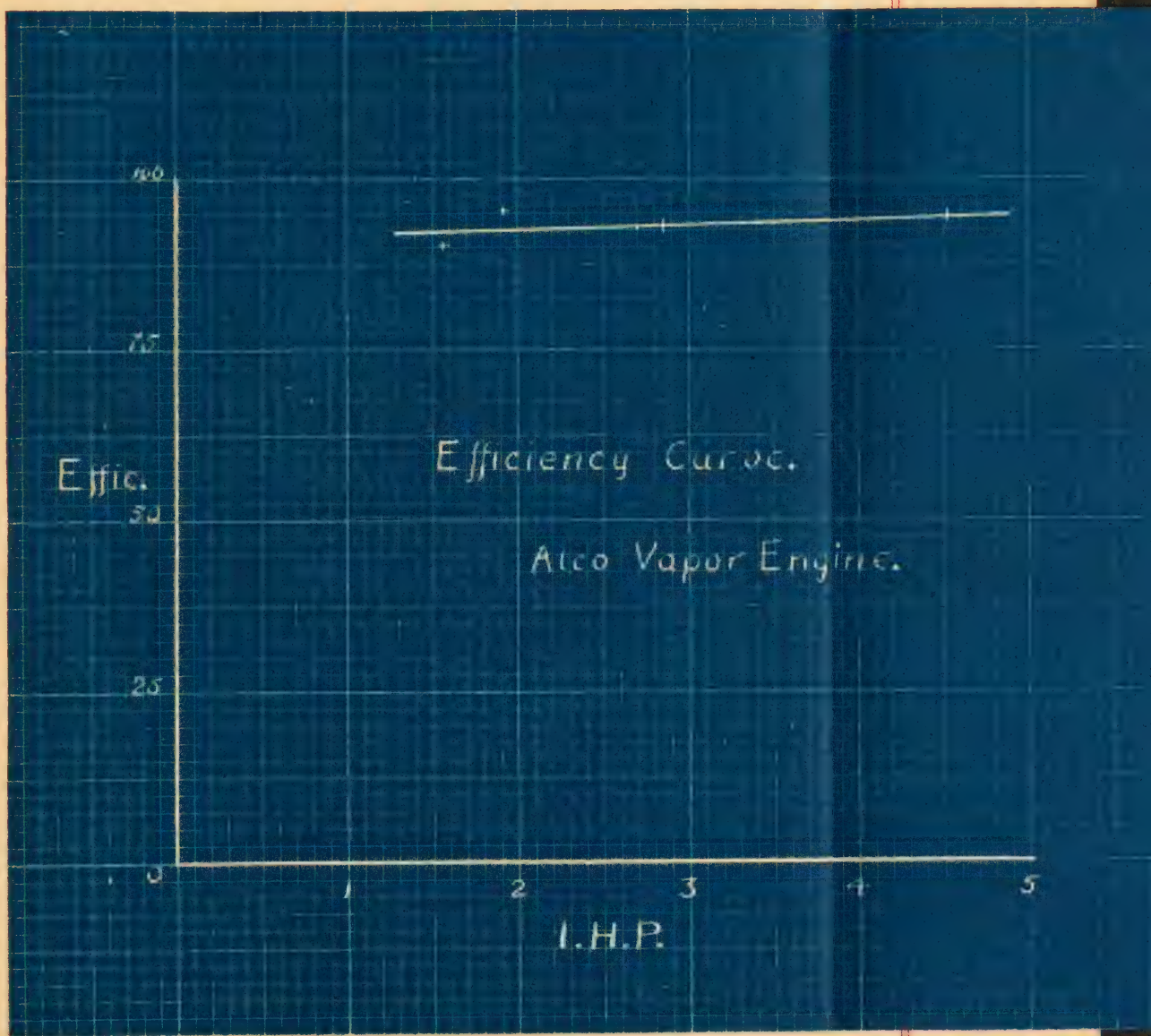
The next card shows an I.H.P. of 2.85 or 5% less than the naked H.P. The mechanical efficiency at this point was rather high and the water consumption averaged 84 lbs.

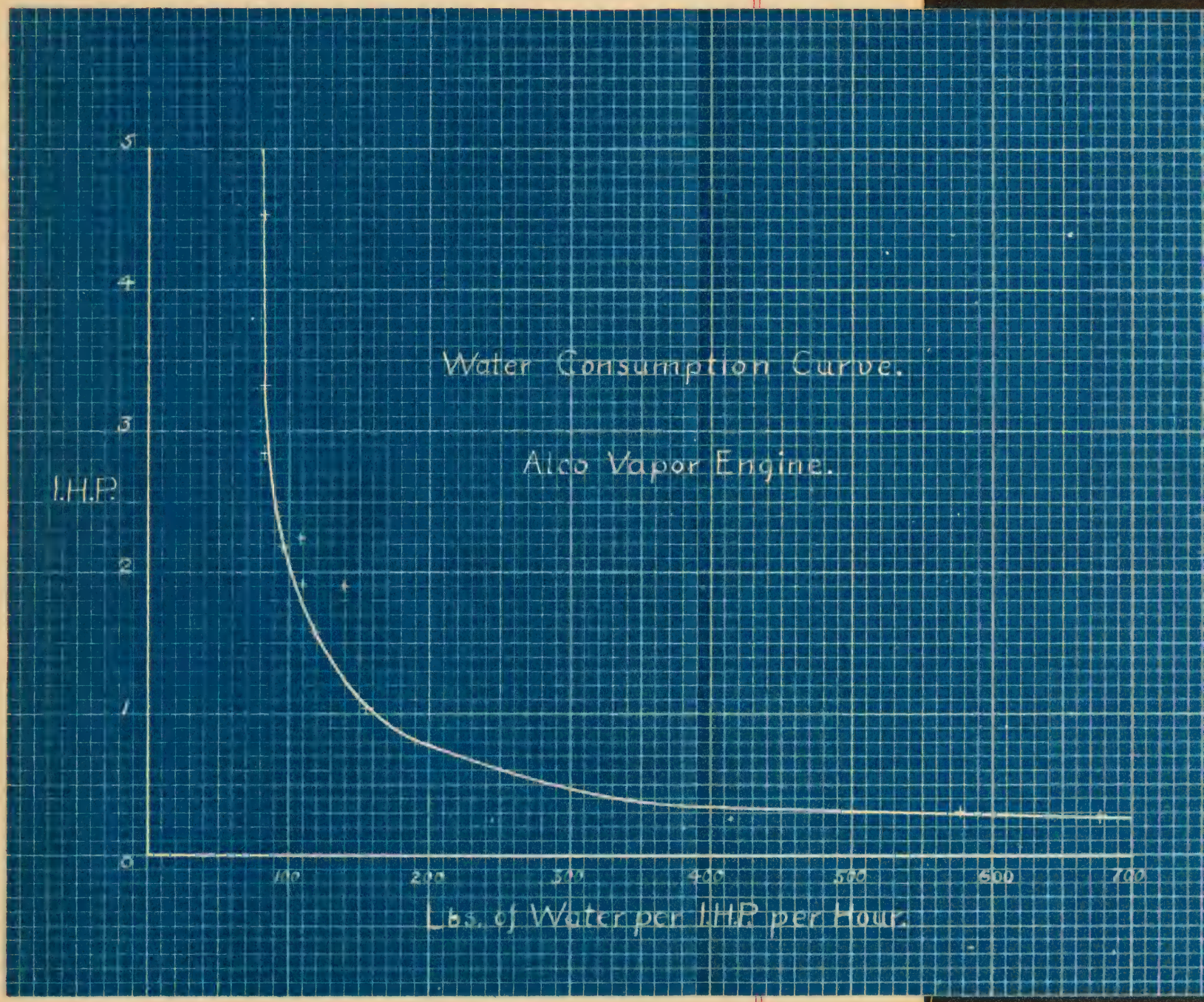


In the previous card shown, steam was carried for about ⅓ stroke. Beyond this point the engine developed more than its rated horse-power and by carrying steam for ⅔ stroke an excess of over 50% of the rated I.H.P. was gotten. This was done without any reduction, practically, in the mechanical efficiency and with a saving of 3 lbs. of water per I.H.P. per hour. It was deemed inadvisable to carry the load further.



A summation of the results will be found in the following diagrams, for the efficiency and water consumption.




Water Consumption Curve.
Alco Vapor Engine.
I.H.P.
5
4
3
2
1
0
100
200
300
400
500
600
700
Lbs. of Water per I.H.P. per Hour.

Calibration of Forschner Spring Balance used in weighing water. It will be seen that the error is constant and therefore does not affect the results.

Standard	Balance	Standard	Balance
0	$-\frac{1}{16}$	$16\frac{1}{2}$	$16\frac{11}{16}$
Pan	$2\frac{9}{16}$	$17\frac{1}{2}$	$17\frac{5}{8}$
$3\frac{1}{2}$	$3\frac{9}{16}$	$18\frac{1}{2}$	$18\frac{5}{8}$
$4\frac{1}{2}$	$4\frac{9}{16}$	$19\frac{1}{2}$	$19\frac{5}{8}$
$5\frac{1}{2}$	$5\frac{9}{16}$	$20\frac{1}{2}$	$20\frac{5}{8}$
$6\frac{1}{2}$	$6\frac{9}{16}$	$21\frac{1}{2}$	$21\frac{5}{8}$
$7\frac{1}{2}$	$7\frac{9}{16}$	$22\frac{1}{2}$	$22\frac{5}{8}$
$8\frac{1}{2}$	$8\frac{5}{8}$	$23\frac{1}{2}$	$23\frac{5}{8}$
$9\frac{1}{2}$	$9\frac{5}{8}$	$24\frac{1}{2}$	$24\frac{5}{8}$
$10\frac{1}{2}$	$10\frac{5}{8}$	$25\frac{1}{2}$	$25\frac{5}{8}$
$11\frac{1}{2}$	$11\frac{5}{8}$	$26\frac{1}{2}$	$26\frac{5}{8}$
$12\frac{1}{2}$	$12\frac{5}{8}$	$27\frac{1}{2}$	$27\frac{5}{8}$
$13\frac{1}{2}$	$13\frac{5}{8}$	$28\frac{1}{2}$	$28\frac{5}{8}$
$14\frac{1}{2}$	$14\frac{5}{8}$	$29\frac{1}{2}$	$29\frac{5}{8}$
$15\frac{1}{2}$	$15\frac{5}{8}$	———	———

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